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NTIA
Air Touch Communications
COMSAT LABS
SFA
ARRL
Rockwell

Appendix 3.8.2
IWG-3 - MSS ABOVE 1 GHZ
LIST OF DOCUMENTS

| No. | Source | Title |
|------|-------------|---|
| 01 | Richards | Agenda - June 16, 1994 |
| 02 | WRC-93 | Res. 1 -Agenda for WRC-95 |
| 03 | IAC | IWG-3 Terms of Reference |
| 04 | IAC | IWG-3 Proposed Work Program |
| 05 | IAC | Proposed IAC Meeting Schedule |
| 06 | Richards | Meeting for IWGs 3, 4 & 5 |
| 07 | Jansky | 1-3 GHz MSS Spectrum Requirements |
| 08 | WRC-93 | Rec. 2, MSS Networks Published Under Res 46 |
| 09 | ITU-RB | Report on the Experience of the RB in the Application of Res. 46 |
| 10/2 | Levin | History of MSS International Allocations |
| 11/2 | LTaylor | Spectrum Requirements Section of IWG-3 Preliminary Report |
| 12 | Levin | Proposal for the Bands 1530-1544/1626.5-1645.5 MHz and 1545-1559/1646.5-1660.5 MHz |
| 13 | Barmat | Proposal for FN 731E, 1610-1626.5 MHz |
| 14 | Sullivan | Proposal for the Band 1675-1710 MHz |
| 15 | Binckes | Proposal for FN 746B, 1970-2010/2160-2200 MHz |
| 16 | Levin | Proposal for the Bands 2010-2025/2165-2170 MHz |
| 17/2 | Lewellen | Proposal for Revision of Power Flux Density (PFD) Limits in the 2483.5-2500 MHz Band as Provided in Footnote 753F and RR 2566 |
| 18 | Binckes | Proposal for Rec. 2, MSS Networks Published Under Res. 46 |
| 19 | Jansky | Experience with Application of Resolution 46 and Associated RR Provisions (TG 8/3-12) |
| 20 | Carroll | Regulatory, Operational and Technical Constraints, 1492-1525 MHz Band |
| 21 | Lepkowski | Relative Status of Services in FN 731E |
| 22 | DiLapi | Modification of the Date of Entry into Force of 2 GHz MSS Allocations |
| 23 | Jansky | A Framework for pfd Triggers in the MSS Bands |
| 24 | Jansky | Implementation of NGSO MSS Coordination Method |
| 25 | Binckes | Applicability of RR 2566 to FN 746B |
| 27 | Levin | Mobile Satellite Service Allocations in the 2500-2535 MHz (space to Earth) and 2670-2690 MHz (Earth to space) Bands |
| 28 | Ladson | Minutes - June 16, 1994 Meeting |
| 29 | EC | Comments on FCC Notice of Proposed Rulemaking |
| 30 | ITU Council | Future Conferences of the Union |
| 31 | Fisher | Minutes - July 5, 1994 Meeting |
| 32 | Long | Summary of ITU-R Activities 1452-1525 MHz |

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| 33 | Binckes | Method for Converting MSS Voice Traffic Demand Forecasts into Spectrum Requirements (MSS Networks above 1 GHz) |
| 34 | Fisher | Minutes - July 19, 1994 Meeting |
| 35 | Fisher | Minutes - August 16, 1994 Meeting |
| 36 | Levin | New Mobile-Satellite Service Allocation in the 1559-1569 MHz Band (space to Earth) |
| 37 | Jansky | Contribution to Regulatory Issues Section (VI) of IWG-3 Preliminary Report |
| 38 | NTIA | Spectrum Use Summary, 137 MHz - 5 GHz |
| 39 | Binckes | Draft IWG-3 Report Element: section IV.A, Advancement of Date of Entry Into Force-FN 746B |
| 40 | LTaylor | Outline for U.S. Proposals Section of IWG-3 Preliminary Report |
| 41 | Gould | Footnotes RR 731E and 733E to the 1610-1626.5 MHz Band |
| 42 | Lewellen | Draft Text for Section IX of IWG-3 Preliminary Report, Recommendations for WRC-97 Agenda |
| 43 | Fisher | Minutes - November 8, 1994 Meeting |
| 44 | IWG-3 | Preliminary Draft Report |
| 45 | Rinaldo | Minutes - December 13, 1994 Meeting |
| 46 | Fisher | Minutes - January 4, 1995 Meeting |
| 47 | Fisher | Minutes - January 18, 1995 |
| 48 | Rinaldo | Minutes - February 2, 1995 Meeting |
| 49 | LTaylor | Revised Section 3.2.2 on Future Spectrum Requirements |
| 50 | Di Lapi | Section 3.3.3 of IWG-3 Interim Report: Generic Allocations |
| 51 | Richards | Schedule of Meetings for IWG's 3, 4 and 5 |
| 52 | Levin | Future ITU-R Studies of MSS Allocations in the 1-3 GHz Range |
| 53 | Rinaldo | Potential Bands for New MSS Allocation |
| 54 | Sullivan | New MSS Allocations Proposals for 1-3 GHz |
| 55 | Nguyen | Minutes - Ad Hoc Working Group on 2 GHz Transition Plan, February 10, 1995 |
| 56 | Nguyen | Minutes - Ad Hoc Working Group on 2 GHz Transition Plan, February 23, 1995 |
| 57 | Carroll | Minutes - February 15, 1995 Meeting |
| 58 | Keane | Footnote 722C |
| 59 | Fisher | Minutes - March 1, 1995 Meeting |
| 60 | Nguyen | Minutes - Ad Hoc Working Group on 2 GHz Transition Plan, March 10, 1995 |

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Appendix 3.8.3

Report of 2 GHz Transition Plan Ad-Hoc Group to IWG-3

Introduction

The Adhoc Group was formed to discuss the possible development of a transition plan as part of a U.S. proposal for WRC-95 to gradually introduce Mobile Satellite Service (MSS) in the 2 GHz bands before the year 2005 recognizing that existing terrestrial users already occupy these bands. The group had met 4 times since February 25, 1995. The meetings were attended by representatives from Columbia Spectrum Management, the FCC, MSS community (AMSC, COMSAT, Iridium, Motorola, Globalstar, TRW, Celsat), the broadcast auxiliary service (National Association of Broadcasters, Maximum Service TV) and the Fixed Service (American Petroleum Institute, Cellular Telecommunication Industry Association, Utilities Telecommunications Council).

These meetings have been useful in exchanging information on the usage of the 2 GHz bands by the fixed service and in discussing options to accommodate MSS uplinks in the 1990-2010 MHz band overlapped with broadcast auxiliary operation, and other sharing issues between MSS downlinks and fixed services, including the operational timeframe for cut over of Common Carrier (CC) and Private Operational Fixed (POF) services, if these services had to be relocated.

Broadcast Auxiliary Service: Electronic News Gathering

The group discussed the proposals from the FCC in the 2 GHz NPRM in allocation the 1990-2025 MHz and 2165-2200 MHz to MSS for uplink and downlink, respectively. The FCC notes that 1990-2025 MHz band is part of the 1990-2110 MHz band currently used by Broadcast Auxiliary Services, including ENG applications. Therefore, the FCC has proposed to relocate the first 2 ENG channels in the 1990-2025 MHz band into the 2110-2145 MHz band resulting in a contiguous spectrum for ENG from 2025-2145 MHz. The relocation of ENG channels requires the relocation of the CC and POF in the 2110-2145 MHz to higher bands.

Based on information obtained from Comsearch, it is estimated that there are about 10, 150 paths total in the paired bands 2110-2130/2160-2180 MHz for CC and 2130-2150/2180-2200 MHz for POF. Estimates to relocate POF and CC would be about \$2.5 Billion assuming a relocation cost of \$250,000 per path. API and UTC had indicated that 5 years would be too soon to relocate POF but 10 years might be a reasonable timeframe for cut over of FS.

COMSAT proposed to reduce the ENG channel bandwidth from 17/18 MHz to 16 MHz per channel. This reduction in ENG channels would make the band 1990-1998 MHz clear of terrestrial interference for MSS uplink in the initial phase of MSS rollout. The seven ENG channels would then be in the band 1998-2110 MHz.

The broadcast industry objects to such a proposal since it will effectively reduce the channel occupied bandwidth by about 6%. Such a reduction would severely handicap its transition to digital ATV. However, NAB agreed to look into this proposal provided there was a technical proposal from a major ENG equipment manufacturer, such as

Microwave Radio Corp., detailing the exact modifications required for retuning the existing ENG equipment for a smaller bandwidth or indicating whether the equipments would need to be replaced.

The broadcast industry would consider shifting one or two ENG channels to a nearby band provided that they get the same equivalent spectrum, ie 17-18 MHz per channel. It is assumed that the engineering and cost of moving one or two channels is about the same (as long as the move is to adjacent spectrum), because only the frequency generation equipment and amplifiers have to be replaced. This would not apply if the move were to a more distant frequency band.

NAB is undertaking a survey to be completed by May/June 1995, which would be more comprehensive and representative than the one conducted in 1992. The results will indicate not only the number of equipments at each TV station in different markets but also the age of the equipments.

Fixed Services: Common Carrier and Private Operational Fixed

POF services are resigned to moving out of the band because of the FCC's E.T. Order. In fact, there have been no new procurements or license applications by POF, because they have to operate, according the Commission Rules, on a Secondary Basis, as of January 16, 1992 and the expectation that their existing stations will be bought out by Emerging Technology services coming into the 2 GHz bands. In these bands, most of the links are short haul and narrow band because the majority of the long haul stations are in the 1850-1990 MHz bands. The majority of these links employ analog equipment.

Common Carrier equipment is digital and mostly used for cellular inter-city links (newer stations). The number of CC paths has been increasing due to the growth in cellular. However, the total number of paths for both POF and CC has remained about constant since the number of licensed POF paths has been decreasing as well according to information obtained from Comsearch.

On-going Sharing Studies between MSS and FS

COMSAT provided a description of an interference model to analyze the interference from an MSS (e.g., INMARSAT-P) satellite downlink into the FS systems and from the ENG systems into the MSS satellite uplink. The model could be configured either using data based on typical traffic levels or on real FS system locations and characteristics or on both. The critical parameters needed for the FS would be: transmit EIRP, transmit peak gain, operating bandwidths, off-axis gain pattern, path length, and required performance criteria. The results of

the runs would be statistical in nature in showing: on how often a specified interference criteria would be met, the distribution of interference level against frequency of occurrence; and the interference level against time.

The group believes that COMSAT's interference model should be reviewed by National Spectrum Management Association (NSMA) or by TIA Committee TR 14.11 prior to industry endorsement. the TIA Committee TR 14.11 is currently at work on

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FCC INDUSTRY ADVISORY COMMITTEE
FOR THE
ITU 1995 WORLD RADIO COMMUNICATION CONFERENCE

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FINAL REPORT
OF
INFORMAL WORKING GROUP 4

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Jack Wengryniuk
Chair

Michael L. Richmond
Vice Chair

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PREFACE

This Final Report of Informal Working Group 4 of the FCC Industry Advisory Committee for WRC-95 addresses the issue of feeder links for MSS systems intending to operate service links in the 1-3 GHz MSS frequency bands. It was noted by IWG-4 that one U.S. company (Teledesic) has proposed a combined non-GSO FSS/MSS system which intends to operate MSS service and feeder links in the 20/30 GHz Ka-Band. The aspects of this system are not included in this Final Report. As such, Teledesic does not agree with various sections of this report and to that extent this report cannot be regarded as representing absolutely unanimous consensus within IWG-4.

4.1 Introduction

Informal Working Group 4 (IWG-4) of the FCC Industry Advisory Committee for WRC-95 was tasked with developing U.S. industry consensus positions on proposals for preferred FSS frequency bands which could support MSS feeder link spectrum for MSS systems intending to operate service links in the 1-3 GHz MSS bands. As such, the IWG considered a number of issues related to the provision of MSS feeder link spectrum for MSS systems intending to operate service links in the 1-3 GHz MSS bands. This final report represents the views of IWG-4 on this topic.

The Terms of Reference for IWG-4, as adopted by the group were as follows:
"Using the Charter for the WRC-95 Advisory Committee as a basic document, the Terms of Reference of IWG-4 are to draft and justify, for consideration by the Committee as a whole, recommendations for U.S. proposals and positions related to:

- (1) bandwidth requirements for the Mobile Satellite Service (MSS) feeder links;
- (2) additional frequency bands that could be allocated to FSS for MSS feeder links;
- (3) preferred Fixed-Satellite Service (FSS) frequency bands to be used for MSS feeder links, taking account of interference that might be caused to FSS Geostationary satellite systems;
- (4) technical and operational constraints associated with the presently and potentially allocated frequency bands with a view toward facilitating the use of these bands;
- (5) addition(s) to/modification(s) of the existing Radio Regulations, e.g. Articles 27, 28, 29;

- (6) resolutions and recommendations, if any, of World Administrative Radio Conferences which are relevant to (1), (2) and (3) above.

Recommendations for U.S. proposals and positions shall be supported by narrative text indicating (a) the amount, and basis for determination, of spectrum needed for MSS feeder links; (b) the placement in the existing FSS allocations of MSS feeder links; (c) the unmet spectrum requirements for MSS feeder links; (d) the appropriate sharing criteria, if sharing with other services is required; (e) the time frame associated with any unmet spectrum requirements and any re-accommodation that may be required of existing services; and (f) any consequential changes needed to the international Radio Regulations in order to accommodate MSS feeder links."

Mr. Jack Wengryniuk was appointed Chairman of the Informal Working Group, with Mr. Michael Richmond acting as Vice-Chairman. The designated FCC contact was Wilbert Nixon.

In order to undertake studies which would address the various elements of the above Terms of Reference, the following Work Program was adopted by IWG-4:

"When recommending U.S. positions and proposals the committee should consider the following elements of the Work Program:

Agenda Item 2.1(c)

Allocated Spectrum. The informal working group is to indicate the preferred FSS frequency bands which could support the feeder link spectrum requirements of the proposed/potential U.S. GSO and NGSO MSS systems. When identifying the preferred frequency bands the informal working group should include a general rationale for the amount of spectrum required, the selection of a given band or bands, the impact on system feasibility should other than the preferred bands be used, the ability of MSS feeder links to share with the GSO FSS and other services, as appropriate, in the preferred bands, and the feasibility of multiple MSS systems to share the same feeder link bands.

Technical and Operation Criteria. Develop the preferred method of feeder link operation for both GSO and NGSO MSS feeder links for each of the frequency bands being recommended for MSS feeder links. Possible methods of operation could include: coordination methods, PFD/EIRP limits, reverse band working, band segmentation. Where required, recommend coordination thresholds and sharing criteria for MSS feeder links sharing with other services. In frequency bands where co-existence of NGSO MSS feeder links and GSO FSS links is proposed, provide an interpretation as to the application of RR2613 and recommend technical and operational criteria for its application. Should it be decided that change to RR2613 is required, include sufficient justification to support this position and develop recommended text for this change.

Agenda Item 3(d) and/or 2.1 (c)

New Allocations. The informal working group should develop a summary of the expected spectrum requirements for feeder links to proposed/potential U.S. GSO and NGSO MSS systems. When considering the overall spectrum requirements for feeder links the group should evaluate the need for additional spectrum required to support feeder links and provide detailed recommendation as to which bands could be allocated by WRC-95 to support these requirements.

Agenda Item 5

Regulatory Provisions. The informal working group should develop regulatory/procedural provisions, as appropriate, in order to provide for MSS feeder links in the proposed bands. These provisions will be forwarded to IWG-1 for finalization after sufficient discussion/development within IWG-4."

This Final Report contains text pertaining to the Overall Spectrum Requirements for MSS Feeder Links for MSS systems intending to operate service links in the 1-3 GHz MSS bands (Section 4.2), the Considerations Relating to the Choice of Frequency Bands (Section 4.3), Feasibility of Frequency Sharing Between MSS Feeder Links for MSS systems intending to operate service links in the 1-3 GHz MSS bands and Other Services (Section 4.4), Regulatory and Procedural Issues (Section 4.5), and finally, Specific U.S. Proposals for MSS

Feeder Link Bands for MSS systems intending to operate service links in the 1-3 GHz MSS bands (Section 4.6).

Appendix 4.7.1 to this Interim Report contains a listing of the IWG-4 documents considered which led up to this Final Report and Appendix 4.7.2 lists the various participants who contributed greatly to the production of this Report.

4.2 Overall Spectrum Requirements for MSS Feeder Links

4.2.1 The Need for Sufficient Spectrum

Geostationary MSS systems, in general, can utilize FSS allocations for feeder links in a co-directional mode with FSS operations. Thus, Geostationary MSS systems may not require the identification of specific frequency bands for feeder links. However, additional challenges are involved in identifying suitable frequency bands for non-Geostationary MSS systems. As a first step in this process, it is necessary to quantify the amount of feeder link spectrum that is required for first generation non-Geostationary (NGSO) MSS systems. These systems propose to use the bands 1610-1626.5 MHz and 2483.5-2500 MHz for service links.

A number of NGSO MSS systems, intending to operate service links in the 1-3 GHz MSS bands, are currently planned for implementation and it is useful to focus on the feeder-link spectrum requirements for these systems. Feeder link requirements for future non-GSO MSS systems, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, should also be considered however, as the feeder link allocations for currently planned systems may not be adequate to accommodate future systems. Depending on system characteristics, NGSO MSS systems, intending to operate service links in the 1-3 GHz MSS bands, propose to use varying amounts of feeder link bandwidths in the frequency range from 4-31 GHz.

Estimating the bandwidth needs for NGSO MSS feeder links, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, is not the same as estimating the bandwidth needs for GSO systems, although some factors are similar. The factors which

need to be taken into account include: (1) the amount of spectrum in the service link, (2) the number of the reuses of this spectrum, (3) the system design concept, (4) the frequency band of operation, and (5) the coordination flexibility/shareability of spectrum with other systems.

NGSO MSS operators, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, have indicated clear preferences for frequency bands for accommodation of NGSO MSS feeder-links, based on service and system design objectives. Use of frequency bands below 16 GHz may possibly enable systems to employ dual polarization, thus substantially reducing feeder link spectrum requirements. Consequently, in estimating spectrum requirements for systems proposing feeder links below 16 GHz, use of dual polarization has been assumed. Such an assumption cannot be made for feeder link spectrum above 16 GHz.

The feasibility of multiple NGSO MSS systems intending to operate service links in the 1-3 GHz MSS bands sharing the same feeder link spectrum has also been evaluated. Geometric and computer analysis verify that in-line interference will occur when multiple systems use the same feeder link spectrum. However, a variety of techniques, coordinated by the systems, may be available to reduce the frequency of occurrence and duration of in-line interference events to acceptable values. Because the limits of feasibility of multiple systems sharing the same feeder link spectrum has not been fully established (i.e. the total number of NGSO MSS systems which can share the same band), feeder link spectrum requirements under both the assumption that sharing is feasible and the assumption that sharing is not feasible have been developed.

4.2.2 Feeder Links Requirements for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands

Feeder link spectrum requirements for a given system can be roughly estimated using system parameters such as service link bandwidth, frequency reuse factor in service link, number of spot beams per satellite, polarization reuse factor in feeder link and guard band factor. Due to differences in these parameters in each of the many proposed NGSO MSS systems intending to operate service links in the 1-3 GHz MSS bands, varying amounts of

feeder link spectrum in the 4-31 GHz range are required to support each system. The following chart identifies the feeder link bandwidth requirements under the assumption that sharing is feasible, and under the assumption that sharing is not feasible. See Section 4.4.5 which indicates that sharing between at least two NGSO MSS feeder link networks, intending to operate service links in the 1-3 GHz MSS bands, is feasible.

**Current Estimates for Feeder Link Requirements
for First Generation NGSO MSS Systems
Operating Service Links in the 1-3 GHz Band**

| Frequency Range | Spectrum (each direction) Sharing Possible** | Spectrum (each direction) No Sharing |
|------------------------|---|---|
| 4-8 GHz | 200 MHz | 400 MHz |
| 8-16 GHz | 200 MHz | 400 MHz |
| 16-30 GHz | 250 MHz*** | 500 MHz*** |

** Assumes that sharing by two NGSO MSS systems is feasible

*** Use of dual polarization is not feasible

The feeder link spectrum requested for U.S. NGSO MSS networks with service links in the 1-3 GHz MSS bands are as follows:

Motorola: 19.4-19.6 GHz (space-to-Earth)
29.1-29.3 GHz (Earth-to-space)

Globalstar: 5025-5225 MHz (space-to-Earth)
6875-7075 MHz (Earth-to-space)

Constellation: 6825-7025 MHz (space-to-Earth)
5050-5250 MHz (Earth-to-space)

Ellipsat: 6725-7025 MHz (space-to-Earth)
15.4-15.7 GHz (Earth-to-space)

TRW: Priority 1
300 MHz at 19.2-19.7 GHz (space-to-Earth)
300 MHz at 29.0-29.5 GHz (Earth-to-space)

Note: This is an alternative allocation to current proposal for feeder links at 29.7-30.0 GHz/19.8-20.1 GHz

Priority 2
300 MHz at 15.4-15.7 GHz (space-to-Earth)
300 MHz at 18.8-19.7 GHz (Earth-to-space)

AMSC: 18.6-18.8 GHz (space-to-Earth)

28.4-28.6 GHz (Earth-to-space)

or

other FSS (space-to-Earth) and (Earth-to-space) bands per WRC-95 decisions

Note: AMSC's feeder links can share the 18.6-18.8/28.4-28.6 GHz bands with GSO FSS networks.

While development of estimated requirements for currently identified systems provides a baseline for feederlink allocation proposals, revisions to the International Table of Allocations which would permit operation of NGSO MSS feeder links, intending to operate service links in the 1-3 GHz MSS bands, in a wide range of frequency bands would be beneficial.

With regard to feeder link spectrum requirements for future NGSO MSS systems, intending to operate service links in the 1-3 GHz MSS bands, it is difficult at this time to develop fully accurate projections. Space segment design, system architecture, service requirements and the use of techniques such as digital processing can influence these requirements. Such requirements would not necessarily be directly additive to those for the systems currently planned.

4.4.3 Considerations Relating to Choice of Frequency Bands for MSS Feeder Links for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands

4.3.1 Possible Impact on System Design, Operation and Cost

The optimum choice of MSS feeder link frequency band depends upon the particular MSS system characteristics. Because of this fact, and the difference in system characteristics between the various U.S. MSS proponents, it is desirable to obtain allocations for MSS feeder links in several different parts of the spectrum in order to maximize flexibility and the scope for technical innovation in providing MSS to the public.

Although some of the U.S. MSS proponents intending to operate service links in the 1-3 GHz MSS bands have expressed the desire to utilize frequencies in the 20/30 GHz range

(Ka-Band) for feeder links, others have proposed frequencies in lower bands. The following discussion offers a rationale for MSS feeder link provisions in three established FSS frequency ranges.

4-8 GHz (C-Band):

One of the driving factors for the utilization of frequencies between 4-8 GHz (C-Band), despite its heavy use by the FSS, is the desire to design a system that uses global (or near global) coverage feeder link antenna beams. With only one (or a few) feeder link beam(s), a feeder link Earth Station (ES) can be located anywhere in the beam. This gives the MSS operator and host countries a great deal of flexibility in locating and siting feeder links earth stations. This is an important consideration in a system where the exact locations and numbers of the feeder link earth stations are unknown at the design stage.

Additionally, systems using these frequencies can use well developed technology in a band where propagation impairments do not result in significant cost impact. The resulting need for relatively small link margins can be exploited through the use of relatively low cost feeder link earth stations.

8-17.7 GHz (Ku-Band):

One of the advantages of this range of frequencies is that it contains a virtually unused 500 MHz portion of spectrum that is currently included in the WARC-88 Allotment Plan allocations, and 300 MHz of spectrum allocated to the FSS in a footnote to the Article 8 Table with a requirement for use in conjunction with Aeronautical Radio Navigation and/or Aeronautical Mobile (R), subject to Article 14. There are also a number of other FSS bands available at Ku-Band, although coordination with VSAT's, TVRO's, and BSS feeder links may make implementation of MSS feeder links difficult. The desire to avoid the rain fading and site-diversity problems that are inherent at Ka-band also make this band attractive.

20-30 GHz (Ka-Band):

Among the reasons for choosing this part of the spectrum are that at present it is relatively lightly used by operating systems, relatively easy to coordinate, and contains a significant bandwidth allocation. However, proposed FSS systems could occupy virtually all of the bands 27.5-30.0 GHz and 17.7-20.2 GHz, worldwide. In addition, the utilization of narrower feeder link beams on the satellite, without recourse to large satellite reflectors, provides the additional link gain required to overcome rain fade effects. Finally, in system designs which provide for flexibility in the location of feeder link earth stations, due to either increased orbit altitude or the use of inter-satellite links, it is possible to locate feeder link stations in areas of low rainfall, thereby avoiding some of the rain attenuation problems normally associated with this frequency band.

4.3.2 Co-Directional vs. Reverse Direction Use of FSS Bands

Co-Directional Use

In principle, any frequency band allocated to the FSS may be used co-directionally by MSS feeder links without modifications to the Table of Frequency Allocations. In practice, however, it is clear that not all FSS bands are attractive for NGSO MSS feeder link use for MSS systems intending to operate service links in the 1-3 GHz MSS bands. Co-directional sharing would result in "in-line" coupling configurations between GSO FSS and NGSO MSS systems. The magnitude and resultant impact of these "in-line" configurations is dependent upon the frequency band of operation. In general, in-line coupling, and its resultant interference, is less severe and hence more manageable at Ka-Band than it is at either C or Ku-band. This topic is further discussed in Section 4.4.1.

Reverse Band Working

The Reverse Band Working (RBW) concept involves the operation of an MSS feeder link in the opposite direction from the FSS allocation. The use of RBW eliminates "in-line" coupling events but introduces the possibility of satellite-to-satellite and ground station-to-

ground station interference. This will be discussed further in Section 4.4.2 of this report. The use of RBW also introduces additional cost to the MSS systems. The transposing of receive and transmit frequency bands, relative to current practice, means that new hardware developments would be required for operation in the required frequency bands. This consideration is particularly important at the higher frequencies, and in fact renders RBW much less attractive at Ka-Band.

4.4 Feasibility of Sharing Between NGSO MSS Feeder Links for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and Other Services and Between Multiple NGSO MSS Feeder Links Systems

4.4.1 Co-Directional Frequency Sharing Between NGSO MSS Feeder Links for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and GSO FSS Systems

As discussed previously, when NGSO MSS feeder links and GSO FSS links share the same frequency band co-directionally, "in-line" coupling can occur. This "in-line" coupling can result in high levels of short term interference and internationally, short-term interference criteria have been adopted for this case. Through extensive computer simulations of this problem it has been determined that the percentages of time for which short-term interference thresholds would be exceeded would be far greater than is likely to be acceptable for most GSO FSS and NGSO MSS carriers at C and Ku-Band. In addition, the level of operational constraint which would be required in order to meet the short term interference criteria would also be considered unacceptable. Because of this fact, IWG-4 believes that co-directional sharing in the C and Ku-Bands occupied by large numbers of GSO FSS systems is not practicable.

The computer simulations mentioned above, however have also shown that the "in-line" interference situation is less severe at Ka-Band.

In principle, the severity of "in-line" interference can be reduced in a number of ways, which include:

Adaptive power control: In the 20/30 GHz bands, earth stations, and in some cases satellites, will usually incorporate dynamic power control of their carrier levels to compensate for propagation fades. The control mechanisms can, in certain circumstances, be used also to partially compensate for interference increases during "in-line" events.

Geographic isolation: If NGSO satellite feeder links employ narrow spot beams which track their gateway stations, then the interference to earth stations in the GSO network, and to the satellites in the NGSO network, will be reduced by the beam discrimination, if the NGSO gateway stations are geographically distant from the GSO earth stations.

Use of high gain antennas: The frequency and duration of "in-line" events can be reduced by the use of earth stations and satellites with high gain, and therefore narrow beamwidth, antennas.

Path diversity:

- **Satellite diversity:** In NGSO constellations incorporating inter-satellite links it is conceptually possible to avoid transmitting during any "in-line" period by switching traffic to an alternative satellite which is not currently "in-line" with the earth station in question and its GSO satellite.
- **Site diversity:** In certain NGSO or GSO networks incorporating path diversity through two (or more) earth stations concurrently pointing at the same satellite (e.g. for the purpose of mitigating rain fading), it is possible to preclude or automatically reject interference associated with "in-line" events in cases where the earth stations are sited in a geometrically favorable manner.

Other potentially applicable mitigating techniques are listed in Table 1 of Section 4.4.5.2 in connection with co-frequency sharing among NGSO MSS feeder link networks intending to operate service links in the 1-3 GHz MSS bands.

Hence, through the use of interference reduction mechanisms, IWG-4 believes that co-directional sharing may be possible at 20 and 30 GHz.

Later simulations of sharing between systems having large numbers of small antenna diameter earth stations have indicated that co-directional sharing at 20 and 30 GHz may be difficult. Hence, IWG-4 concludes that co-directional sharing may not be possible between all currently planned NGSO MSS systems and planned GSO FSS systems. However, for certain high data rate terminals, which are fewer in number and have larger antenna diameters, co-directional frequency sharing is less difficult.

4.4.2 Reverse Direction Frequency Sharing Between NGSO MSS Feeder Links for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and GSO FSS Systems

Work in international forums has shown that sharing between NGSO MSS feeder links, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, in RBW and GSO FSS systems in the forward band mode is technically feasible in the C and Ku-Bands, including the Allotment Plan bands (i.e. 4500-4800/6725-7025 MHz and 11.20-11.45/12.75-13.25 GHz). This work has also shown this type of operation to be technically feasible in the Ka-Band, however, there are severe practical constraints associated with this type of operation at Ka-Band. The results of analyses indicate that:

- Sharing of NGSO MSS feeder links, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, in RBW mode in the C and Ku-Band FSS allocations is feasible,
- The satellite-to-satellite interference, in both directions, is well within acceptable interference criteria,
- For earth station-to-earth station interference, the coordination distances range from 100 to 300 km in C-Band and 100 to 225 km in Ku-Band and can be further reduced by site shielding,
- From practical considerations of maintaining system costs within reasonable bounds and of minimizing operational constraints on both GSO FSS and NGSO MSS systems, for

MSS systems intending to operate service links in the 1-3 GHz MSS bands, RBW is not preferred in Ka-Band and in congested FSS bands such as those where there exist a large number of earth stations authorized without any requirements for coordination.

Considering all of this, IWG-4 fully endorses the use of RBW in the lightly used FSS bands below 17.7 GHz, recognizing the need for allocation and regulatory decisions at the WRC-95. RBW is an important technique because it provides the NGSO MSS operators, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, with a method for using the FSS bands for feeder links without resulting in unacceptable interference to either GSO FSS networks or NGSO MSS feeder links.

4.4.3 Frequency Sharing Between NGSO MSS Feeder Links for MSS systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and Fixed Service Networks

4.4.3.1 Interference from NGSO MSS Satellite Feeder Links, for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands, into Fixed Service Stations

ITU-R studies of interference from NGSO MSS satellite feeder links, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, into FS stations have shown that sharing is feasible. Some concerns, however, have been expressed as to whether the limits in Article 28 could really be applicable to NGSO satellites. The rationale behind this was that even if the PFD limits in Article 28 are met, "in-line" interference could exceed the maximum C/I criterion for short periods of time.

The following pfd limits are proposed, for those bands which are used by non-GSO/MSS feeder links and are NOT shared bi-directionally with GSO/FSS, or are "lightly" used by the GSO/FSS in the other direction:

6-8 GHz: -154/-144 dB(W/m²/4 kHz)
13-15 GHz: -148/-138 dB(W/m²/4 kHz)

A second set of pfd limits (more stringent than those above) is to be applicable to each non-GSO/MSS satellite operating in RBW mode, in a band "heavily" used by the GSO/FSS:

| | |
|-----------|---------------------------------------|
| 6-8 GHz | -158/-148 dB(W/m ² /4 kHz) |
| 13-15 GHz | -150/-140 dB(W/m ² /4 kHz) |

The lower values are for arrival angles up to 5 degrees and the higher values for arrival angles between 25 and 90 degrees. For arrival angles between 5 and 25 degrees, the pfd limits should be linearly interpolated.

In order to select the appropriate pfd limit, consideration should be given to the use of the band by the FS.

The interest of RBW was certainly sharpened through Recommendation SF 1005 in which it is suggested that below 10 GHz RBW is not feasible because of heavy usage by the FSS, and above 10 GHz PFD limits have to be tightened. Even though Recommendation 1005 had addressed bands above 10 GHz only, for bi-directional usage by GSO FSS, it may be possible to identify bands which are lightly occupied by FS, to accommodate NGSO MSS feeder links for MSS systems intending to operate service links in the 1-3 GHz MSS bands. A set of PFD limits applicable to NGSO MSS feeder link satellites, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, has been proposed for bands that are shared bi-directionally with GSO FSS.

4.4.3.2 Interference from Fixed Service Station into NGSO MSS Satellite Feeder Link for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands

The worst case aggregate interference, from multiple FS transmitters into NGSO MSS satellite feeder uplinks, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, is well within the protection criteria. Concerns have been expressed, however, on the possible interference from trans-horizon systems in the band 4500 - 4800 MHz. The very high transmit power of these systems (in the order of several KW) could make the use of

parts of this band almost impossible for NGSO MSS satellites, for MSS systems intending to operate service links in the 1-3 GHz MSS bands.

4.4.3.3 Interference Between NGSO MSS Feeder Link Earth Stations for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and Fixed Service Stations

Application of Recommendation IS.847 and Recommendation IS.849 can be directly applied to sharing between NGSO MSS earth stations, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, and FS stations. It has been shown that sharing feasibility between NGSO MSS earth stations, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, and FS stations is of the same magnitude as between FSS and FS.

Concerns have been expressed, however, on the number of NGSO MSS feeder-link earth stations, the use of RBW and the number of FS stations. In the first instance, a high density of MSS feeder-link earth stations, for MSS systems intending to operate service links in the 1-3 GHz MSS bands, would certainly make the sharing difficult. However, most of the actual systems proposed today have a range of 25 to 200 stations worldwide (up to 15 stations for one system operating on the contiguous United States). It must also be pointed out that it is expected that different systems will operate in different bands.

4.4.3.4 Reverse Band Working of NGSO MSS Feeder Links for MSS Systems Intending to Operate Service Links in the 1-3 GHz MSS Bands and the FS

It is recognized that if RBW mode is recommended in bands that are not heavily used by FSS, this usage is not expected to suffer from the constraint of another existing interference mode. However, it is noted that in Recommendation SF.1005 RBW was not considered below 10 GHz because of its inapplicability in bands heavily occupied by the FS. This certainly needs to be clarified as several MSS systems, intending to operate service links in the 1-3 GHz MSS bands, are considering reverse band operation below 10 GHz in bands that may not be heavily used by FS. It is then expected that, notwithstanding the existence of